Characterising the acoustic footprint of Australia's new research vessel RV Investigator

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ABSTRACT

The RV Investigator is Australia's new noise quietened Marine National Facility (MNF) vessel built to comply with the DNV silent-R specification. This radiated noise specification was based on the ICES 209 CRR specification designed with the main goal of minimising vessel avoidance for fisheries surveys. Noise quietening was specified for RV Investigator to improve the acoustic detection of instruments and reduce the vessel's noise footprint on the environment for research activities. Traditionally DC propulsion motors are used to achieve radiated noise compliance; in this case AC propulsion motors have been used. Initial noise measurements show the RV Investigator is 20 dB (factor of 100) quieter than the previous MNF vessel, RV Southern Surveyor which will significantly improve acoustic instrument performance. The new acoustic systems on the RV Investigator range from sub-bottom profilers, Doppler current profilers, multi-frequency and multi-beam water-column echo-sounders and low to mid frequency multi-beam bathymetry echo-sounders.

Keywords: Shipboard and offshore platform noise control I-INCE Classification of Subjects Number(s): 13.5, 54.3

1. INTRODUCTION

Acoustic sensing in the ocean requires vessels that produce low background noise to improve the quality and detection range of instruments. Vessel and instrument radiated noise should also minimize impact on marine biota and associated measurements of their distribution and abundance. Vessel radiated noise was suggested to effect the accuracy of acoustic surveys due to fish hearing thresholds and subsequent fish behavior. Based on this hypothesis a vessel noise specification was proposed with a low frequency limit based on fish hearing and a high frequency limit based on acoustic instrument detection (1). After several research vessels were built that met and exceeded this ICES209 specification a simple link between vessel noise and fish behavior has not been proven (2). It has been demonstrated that fish avoidance of an approaching vessel can bias acoustic biomass estimates although the nature and magnitude of this bias varies with and without a noise reduced vessel. The stimuli that influence fish avoidance requires more research and it is recommended to carry out surveys of fish when they are in a less reactive state (2).

Based on the ICES209 noise radiation from vessel specification, a DNV silent-R specification was developed that modified the low frequency range (3). The objective of this specification was targeted at research vessels to improve detection of sensitive acoustic instruments and reduce the acoustic noise footprint on marine habitats and biota. The specification is 20-30 dB lower than many commercial fishing vessels and significantly less than Australia's previous MNF research vessel RV Southern Surveyor (Figure 2). Australia's new research vessel the RV Investigator was built to comply with the DNV silent-R specification. At low frequency radiation DC propulsion motors are normally recommended to meet the DNV silent-R specification, the RV Investigator is fitted with AC propulsion motors. To meet the high frequency radiation specification the propeller housing and type is important, with controllable pitch propellers being very noisy, as used on the RV Southern Surveyor. The RV

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Investigator is fitted with two five blade fixed pitch propellers to reduce high frequency noise(1).

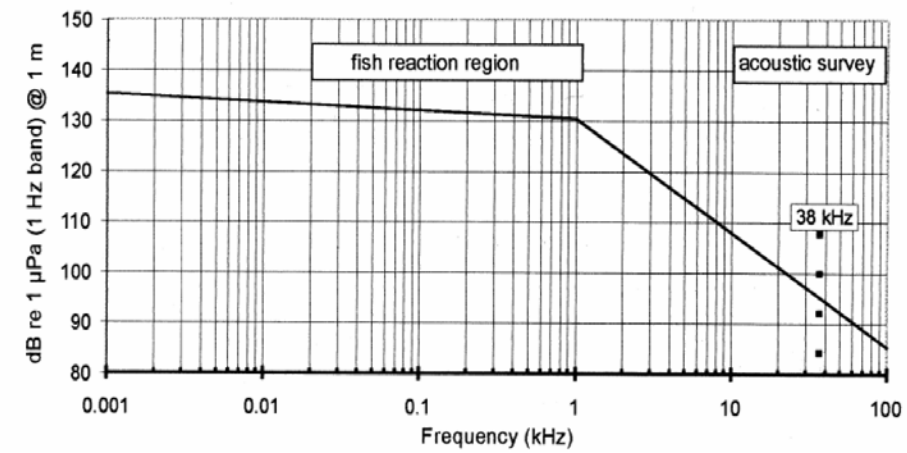

Figure 1 ICES209 recommendation of underwater noise at 11 knots free-running for vessels used in fisheries research(1).

In this work we compare the vessel noise and instrument capabilities between the RV Southern Surveyor and RV Investigator and provide some preliminary findings in shallow water. After some delays the vessel is due at its home port on the 9th September 2014. This delay has impacted the data available for this paper as comprehensive acoustic trials will be done as part of the commissioning of the vessel in late 2014.

2. EQUIPMENT AND RESULTS

2.1 Radiated noise comparison RV Investigator and RV southern surveyor

The functional requirement for the 93.9 m, 6082 gross tonnage, RV Investigator to deliver a low noise research platform for science was key to the design process for the vessel. The benchmark in achieving this performance is the DNV Silent-R class notation from Det Norske Veritas which specifies the allowable radiated noise for research vessels in the frequency band 10 Hz to 80 KHz(3). Verification of compliance with Silent R was undertaken through direct measurement of radiated noise using a seafloor mounted hydrophone coupled with spectral acquisition and analysis tools. Noise measurements were collected as the vessel transits past the fixed seafloor hydrophone in accordance to prescribed range and speed constraints defined by the DNV Silent Class Notation(3). In order to achieve Silent Class Notation many critical aspects of the vessel design must be addressed at the outset. These include hull shape, propulsion, isolation of machinery vibration and propeller design.

In comparison the 66.1 m, 1594 gross tonnage RV Southern Surveyor was built as a factory stern trawler in Hull England in 1976 and designed for sea-worthiness and functionality in this role with little attention to radiated noise. Surveyor's propulsion system comprises a Wartsila diesel engine driving its variable pitch four blade propeller through a gearbox and clutch (Figure 2). The Wartsila engine and three additional independent diesel power generators on the ship are simply mounted using conventional resilient mounts.

Joint venture company RALion comprising Robert Allan Naval Architects and Marine Engineers and Alion Science and Technology undertook the vessel design of RV Investigator. The vessel hull was derived from existing research vessel builds with specific modifications to suit the custom acoustics systems and functionality demanded by RV Investigator. Vessel models were constructed and studied in flume tank tests to verify hull efficiency, bubble sweep down and noise performance.

Propulsion for RV Investigator is entirely designed for DNV Silent R compliance. Twin five blade screws manufactured by Wartsila each 3.5 meters diameter were specially design to be cavitation free at 11 knots (Figure 2). This speed is consistent both with the nominal vessel survey speed and matches the DNV Silent R compliance measurement speed. The propellers are driven by two primary

propulsion motors manufactured by L3 operating at 690VAC, 2600KW. AC power for these motors comes from two Ingeteam 3MW LV400 water cooled converters which provide variable speed drive capability. In addition switching frequencies for the converters have been chosen to minimize radiated noise and vibration into the water. Primary vessel power to service the propulsion and all other vessel demands is delivered from three Mak 9M25C diesel generators. A custom RALion designed raft system coupled with double resilient mounting provides isolation of these generators from the vessel hull to achieve low vibration transmission. Finally hull plate surfaces within the engine room and propulsion spaces are internally coated with sound absorbing paints to further reduce the radiation of noise into the water.

Table 1 summarises the key aspects of the RV Investigator design which contribute to achieving meet DNV Silent R compliance. Measurements undertaken by contracted noise engineers under the supervision of Lloyds Register during Sea Acceptance Trials verified that RV Investigator successfully achieved DNV Silent R Class Notation (Figure 3).

Table 1 Comparison of Vessel Noise mitigation measures Southern Surveyor/RV Investigator

Design Feature	RV Investigator	Southern Surveyor
Hull Design	Custom design by RALion joint venture. Robert Allan Naval Architects and Marine Engineers	1970's design stern trawler built Hull, England
Propellers	Twin 5 blade Wartsila 3.5 m diameter.	Single 4 blade conventional design variable pitch
Propulsion	2 x L3/Indar 690V AC 2.6kW motors powered by 3 Mak 9M25C diesel generators	Wartsila marine diesel via gearbox to propeller
Resilient Mounts	Mak generators – raft system with double resilient mounts. L3 AC drives resilient mount rotors	Single resilient mount
Specialised Coatings	Internal hull plates coated with sound absorbing paint	Nil

Figure 2 The propeller type has a big impact on high frequency radiated noise due to bubble cavitations. The RV Southern Surveyor (left) had a 4 blade variable pitch propeller whereas the RV Investigator (right) has a five blade propeller optimized for low cavitation at the 11 knots.

The noise spectra of the RV Southern Surveyor steaming at 2-12 knots were recorded for a wide variety of operating conditions at the Jarvis Bay sound range in November 1994 (4). The low frequency spectra from 50 to 1 kHz varied by 20 dB based on the operating conditions. At the survey speed of 10 knots the RV Investigator was well above the ICES209 standard (Figure 3). The RV Investigator was tested in Singapore based on DNV procedures (3). The tests show that the vessel noise at 11 knots steaming speed is well below the ICES 209 standard at the high frequency end and 20 dB less than the RV southern surveyor. Further tests of the RV Investigator will be done during the commissioning of the vessel following the DNV procedures (3).

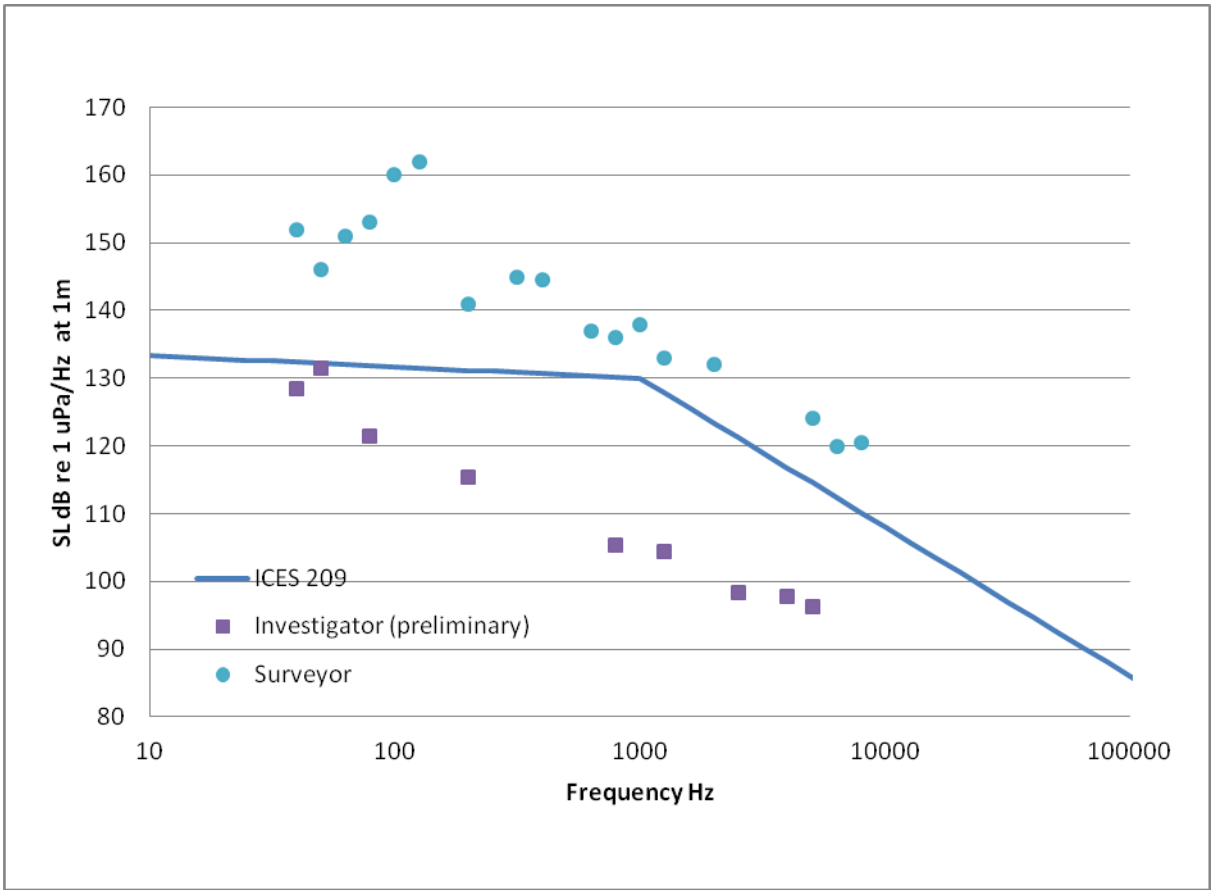

Figure 3 Vessel noise spectra in dB re 1 uPa in 1 Hz bands at 1 m for the RV southern Surveyor (circles) and the RV Investigator (squares) compared to the ICES 209 recommendation (solid line). Note that measurements were reported in 1/3 octave and have been converted to Hz band.

2.2 Scientific instruments on RV Investigator

The RV Investigator is fitted with a range of sub-seabed, seabed, water column acoustic sensing equipment using multi-beam and split beam transducers incorporating, doppler, broadband, narrow and multi-frequency processing (Table 2).

Table 2 RV Investigator acoustic instruments with nominal beam angle, operating frequency and source level

Type	Model	Nominal Beam width (degrees)	Nominal operating frequencies (kHz)	Nominal source level (dB re 1 µPa RMS) at 1 m
Seabed Multibeam	EM710	0.5 x 1	70 - 100	232

Seabed Multibeam	EM122	1 x 1	12	242
Sub bottom profiler	SBP120	3 x 3	2-8 kHz + 12	230
Environmental Multibeam	ME70	2	70-120 kHz	
Environmental Echosounder	EK60	7 to 10	18, 38, 70, 120, 200, 333	*222*
Seabed Echosounder	EA600	7 to 14	12,18,38,120,710	
Sonar	SH90		114 kHz	
Current Profiler	ADCP		75 kHz - 150 kHz	

Due to their size seabed multibeam transducers are mounted within a gondola under the vessel hull which reduces interference due to bubble sweep down. The ecosystem echo sounders are housed in a keel that can be lowered 4 m under the hull of the vessel that has been shown to greatly increase data quality in rough seas (Figure 4) (5).

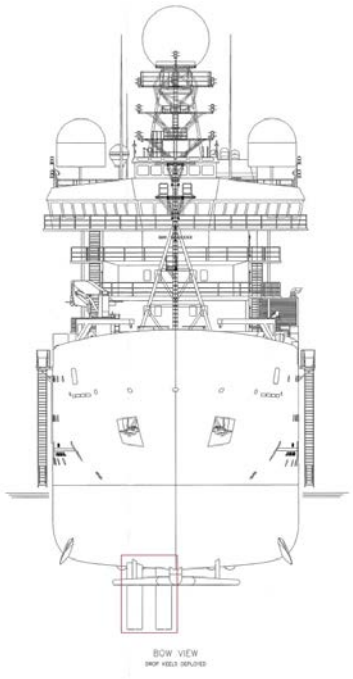

Figure 4 Drawing of the RV Investigator with the lowered drop keels (highlighted in red box) that house the environmental echosounders and the gondola that houses the multibeam transducers.

2.3 Acoustic Instrument Trials on RV Investigator

Noise tests of the sonar acoustics were undertaken during the sea trials for RV Investigator, to determine baseline noise values for the systems and establish the risk of interference, such as from frequency tones or propeller cavitation, with the acoustic systems. Noise tests were also undertaken to measure the effect of remediation work on the propeller and DNV Silent-R compliance.

Noise tests were undertaken for most of the suite of acoustic instruments, at speeds increasing from 1 knot to 14 knots at 1 knot increments. Propulsion was then removed from the propeller and the vessel was allowed to coast to a stop. The method of the noise tests varied according to the instrument's capability. Noise tests for all instruments were undertaken simultaneously with the exception of the ME70.

The noise tests were undertaken in 50-60 m of water (average water depth 53 m), in the approximate location 01° 22' N, 104° 27' E. The sea state varied slightly, with an average Beaufort reading of 2. The relatively shallow depth in which the tests were taken will have the effect of increasing measured noise due to sea bottom reflectance and high levels of biological-derived water column noise (suspected snapping shrimps). Deep water noise tests will be required to compare the RV Investigator with the RV Southern Surveyor and is part of the vessels commissioning trials which will be reported on at the meeting.

Despite the noisy environment in which the tests were conducted, preliminary analysis of the relative noise levels for the Kongsberg EM710 and EM122 on RV Investigator show a 5 to 10 dB improvement in performance between the RV Investigator systems underway and wharf side measurements of the RV Southern Surveyor's EM300. Underway noise levels for the RV Southern Surveyor would be higher than those represented here due to radiated engine and propeller noise.

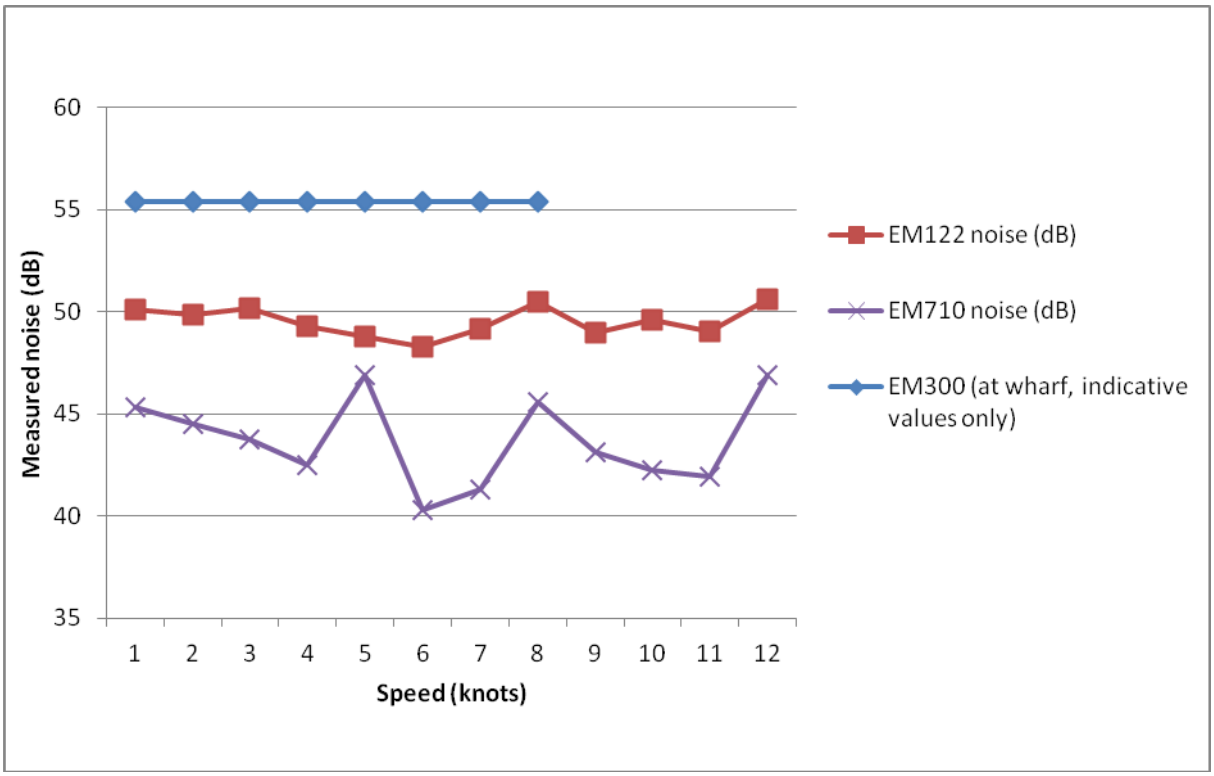

Figure 5 Received relative noise (dB) in passive mode at varying speed for the EM122 and EM710 systems onboard RV Investigator. Averaged wharf side relative noise (dB) test values for the EM300 onboard RV Southern Surveyor have been included for reference, but do not correspond to vessel speed.

2.4 Discussion

The RV Investigator has achieved the DNV Silent-R noise radiation specification using an AC propulsion motor with five blade propeller and at high frequency has a noise spectrum 20 dB (factor of 100) less than the RV Southern Surveyor. This low radiated noise is observed in the noise tests of the multi-beam seabed mapping equipment where there is a 5-10 dB improvement when compared to the RV Investigator moving at 11 knots in shallow water to that of the RV Southern Surveyor at the wharf. We expect all the RV Investigator instruments to outperform those of the RV Southern Surveyor by up

to 20 dB in the deepwater trials operating at 11 knots vessel speed. Further noise testing was undertaken during the delivery voyage of RV Investigator, from Singapore to Hobart in August-September 2014. Results were not available for this paper but noise spectra from the full suite of acoustic instruments will be presented at the conference.

The impact on the environment due to vessel radiated noise has been significantly reduced (~ 20 dB) when compared to the RV Southern Surveyor. This has been achieved with AC propulsion motors and which are cheaper, smaller and have lower maintenance costs than DC propulsion motors. This type of noise reduction for all vessels could significantly reduce global shipping noise in the marine environment. Active acoustic instruments also emit sound of high intensity but on RV Investigator these are very directive and at short pulse lengths. Impact on marine mammals from these echo sounding instruments is not thought (given current knowledge) to pose a risk, although potential effects on behavior require more research (6). The effect of radiated noise on other marine life (e.g. fishes and invertebrates) has also been reduced although the impact (e.g. behavior) of noise on these biota is not well understood (7).

The vessel's reduced radiated noise will have measureable beneficial impacts on the acoustic instruments. Firstly, for seabed mapping it will enable the vessel to more efficiently map deeper and larger areas and resolve seabed habitats. Secondly, the suit of ecological echo sounders will be able to penetrate deeper and resolve weaker targets. For multi-frequency target classification it will have a significant beneficial impact on the discrimination of pelagic habitat to deeper depths and in a wider range of weather conditions. The RV Investigator contributes the multi-frequency acoustic data to Australia's Integrated Marine Observing System (www.imos.org.au) with national and international uptake. Use od drop keels for the environmental echo sounders should provide higher quality data over a much larger range of weather and sea conditions.

ACKNOWLEDGEMENTS

We would like to thank the CSIRO's Marine National Facility implementation team for their dedicated work over many years to deliver this noise reduced vessel.

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